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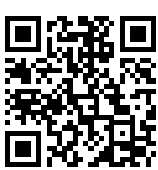

A LECTURE

ON

THE EDUCATION OF CIVIL AND MECHANICAL ENGINEERS

IN GREAT BRITAIN AND ABROAD,

BEING A PUBLIC INAUGURAL ADDRESS DELIVERED IN THE UNIVERSITY OF EDINBURGH,

BY FLEEMING JENKIN, M.I.C.E., F.R.S.,

ON TUESDAY THE THIRD OF NOVEMBER 1868,

AT THE COMMENCEMENT OF THE FIRST COURSE OF LECTURES DELIVERED FROM THE CHAIR OF ENGINEERING ENDOWED BY SIR DAVID BAXTER AND BY GOVERNMENT.

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GENTLEMEN,—

THE recent demand for improved technical education in Great Britain, which originated, I believe, with Dr. Lyon Playfair, has been re-echoed from all quarters so loudly and persistently as to leave no room for doubt that a real want existed, that some real defect was felt in the education of those whose business it is to produce wealth by skilled industry and by intelligent invention, in other words, of those men on whom the material power of our country rests. The importance of this education is so well known that we have seen chambers of commerce and workmen's clubs, learned societies and the public press, universities and Government departments, trade-unions and a committee of the House of Commons, all engaged in discussing the measures to be taken. But while many men have talked, earnestly enough, some few men have acted, and the foundation of the chair of Civil Engineering in Edinburgh is due to one of those few, to one who has by his benefactions merited the thanks of *all* interested in the advancement of learning, and to whom, especially you, the friends of this great University, owe sincere and hearty gratitude,—need I name Sir David Baxter?

The motives for your feelings are clear and easily expressed. In Sir David Baxter you see a man who devotes

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his wealth to a great object, who honours science, and enlarges the functions of that University which for many generations has made your city one of the great centres of learning. You also hope that this new branch now grafted on the old tree will in time bear fruit commensurate in value with the results gained by the foundation of those ancient Chairs which for generations have been of inestimable value to Scotland, and of great service to civilisation. Knowing that these hopes and expectations are rightly held by all, and most of all by the founder of the Chair, believing also that the work done by the engineer is second to none in its importance to our country, my own feelings are more complex and difficult to express. I enter upon my duties with a sense of responsibility so serious as to damp in great measure those feelings of satisfaction which would otherwise be the legitimate consequence of the great honour done me by my appointment to this chair. Mere verbal acknowledgments from me now would have little value. It is by my work in future years that my gratitude must be shown. I know the difficulty and the importance of the work to be done. What I can do I will do.

What to do is the question. In most departments of knowledge precedents lie to the hand of the Professor. Doubtless the teaching of any man of real talent will always contain much that is due to the man himself; but in classics, mathematics, and many branches of applied science, the methods of teaching are reduced in great measure to a system, and for these studies the student can find text-books of acknowledged excellence; not only has the country he will traverse been surveyed, but roads more or less passable lie before him, leading to well-known ends. The subjects of examination and the standards of excellence are also tolerably defined; but the engineering student has hitherto enjoyed none of these advantages, and a Professor of Engineer-

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ing in this country finds that he has still to create that system of instruction which in other Faculties needs only to be developed and improved.

One brilliant exception proves the truth of this assertion by the very clearness with which it shines in the general gloom. I refer to the sister University of Glasgow, where Professor Rankine has taught a class, continually increasing in numbers and importance—has written a series of text-books combining originality and sound practice more admirably than any I am acquainted with in any language, while by his genius for research and bold speculation, he has rendered his Chair of Engineering famous throughout the world, and has done as much to relieve our profession from the general charge of ignorance in the higher branches of theory as was possible to any one man.

But one man, however great his powers, is not enough, and even if it were possible for me to follow in the brilliant path indicated by Professor Rankine, it is not desirable that all the teaching should be of one type. When, therefore, I received my appointment to this Chair, I determined, personally, to examine the methods employed on the Continent for the instruction of engineers who receive a systematic education in public colleges of great magnitude. How far it is possible or desirable to imitate the work done in these institutions is a question of importance to us all, and of the greatest possible moment to myself.

The position of an engineer abroad, in general, differs much from that of his English colleague or competitor, and in France the difference is greater than in any other country.

The distinction existing here between civil and mechanical engineers is far more strongly marked in France. And the business of the civil engineer, who is occupied with roads, railways, canals, rivers, harbours, mines, is almost exclu-

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sively in the hands of the members of the body called the Engineers of the *Ponts et Chaussées*, forming an important branch of the public service. These Government officials correspond to our civil engineers; they are allowed, and even encouraged, to enter the service of private companies and large establishments, but remain all their lives members of their corps; and supported as they are by Government patronage, by tradition, by their *esprit de corps* and mutual assistance, and lastly, by their acknowledged distinction and honourable conduct, they enjoy so great an advantage over any independent man who may try to compete with them, that the civil engineer proper only exists as an exception in France. Once a member of the corps, a man is honourably provided for in life: he enjoys rank, certain promotion, a fair income, and, if he have original talent, a certainty of opportunities of largely increasing that income. Nothing, you will see, can possibly be more different from the career of an English engineer, to whom the Government is usually nothing, unless it be looked upon as a foe from whom recognition and remuneration is to be won by sheer hard fighting.

Being public servants, French engineers are educated by Government, and in great part at Government expense; the career, being so advantageous, is desired by the *élite* of the French youth, and hence in the competition which determines the admission of students to the Polytechnic School, as the school of engineers is termed, we see 900 picked pupils of eighteen and nineteen, each straining every nerve to win one of 150 appointments annually made. I believe that there exists no competition in Europe comparable with this. The great severity of the examination is so well known, the fact that five out of six must fail is so obvious, that none but young men who have already gained distinction in the great public schools dream of competing. I remember when myself at school in France, the mere fact that a lad had

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determined to enter the arena, rendered him an object of awe and admiration to all of us years before the final trial came. In this trial they are examined in plane and solid geometry, in analytical geometry of two and three dimensions, descriptive geometry up to curved surfaces, algebra including the general theory of equations, series, functions simple and derived, etc., physics, chemistry, an odd language or two, and shaded mechanical drawing. An English engineer reading the list of subjects is tempted to exclaim, "What more can they want before beginning the practical part of their profession?" But the select 150 are a long way yet from that. For two years longer they are employed in purely theoretical studies, that is to say, the higher mathematics, theoretical mechanics, mathematical physics, curious problems in descriptive geometry, with a little drawing and language as recreations. During these two years each of the 150 is engaged in a daily struggle for about five-and-twenty highly-coveted posts. The three who are at the head of the class-list at the end of the two years gain the proud title of Engineers of Mines, the rest are humbler members of the *Ponts et Chaussées*, while the 125 who fail have to content themseves with looking after the State factories for powder, tobacco, or saltpetre, or, worse still in their estimation, they sink into mere royal engineers or artillerymen. They may even fall as low as the navy or marine-artillery, for, strange as it may seem with our misconceptions of the French character, the civil appointments rank infinitely higher in the estimation of the competitors than the military posts.

Thus we see that nearly 900 picked pupils compete fiercely, in the hope of ultimately becoming one of the five-and-twenty who may bear during their lives the coveted title of Engineer. And the five-and-twenty thus annually selected are practically the only recruits received by the whole body of French civil engineers. As we have not five-and-twenty

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prizes of an analogous nature to offer, I very much fear that considerably fewer than 900 students will besiege my class-doors here, and yet I am not wholly without hope that in time five-and-twenty men may leave this College yearly who shall not be much less valuable to their country as engineers than the five-and-twenty prizemen of the great French school.

Let us accompany them a little further on their career. They have not yet got to practical work. For three years they attend another school, the school of the *Ponts et Chaussées*, or the school for engineers distinctively. Here they are taught in classes how to apply their theoretical knowledge to practical problems, and for six months in each year they are sent into the country to see some practical work; there are no more competitions, and the life is now an easy one; at the age of about four or five and twenty they leave college and are sent into the provinces to begin real work, which for them is chiefly a matter of routine, concerning the administration of the law as to the maintenance of all public works under Government control or inspection,—*i.e.*, in France, roads, canals, rivers, harbours, railways, and telegraphs. Too often the young man who has received a mathematical training equal to any that Cambridge can give, sinks into apathy under this occupation, and plods his life through in a lazy comfort, without ambition, but with no fear as to the future, without failure, but without success. This will hardly be the fate of a young man leaving a Scottish university, and therefore my hope is not presumptuous, that, fairly equipped with a knowledge of the principles which in practice engineers are called upon to apply, spurred on by the necessity of making their daily bread, by a noble ambition for distinction, and by the energy of the national character, our students may go out into the world with the hope and the determination that they to their country will not be of less value than the highly trained athletes of France.

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In the education given to mechanical engineers in France, we find much that is worthy of our admiration. Their mechanicians form no guild, protected against competition; they have to work and strive, subject to the same hard laws which determine commercial success abroad as at home, and they are rivals whom we must respect, if we do not fear them. Their marked success of late years has chiefly led to the demand for a better technical education in England, it being well known that much of their success was due to the excellent education which they received, chiefly in the École Centrale of Paris—where the instruction given is very similar to that offered by the great polytechnic schools of Germany and Switzerland. These great colleges at Zürich, Carlsruhe, Stuttgardt, and several other German towns, offer, with the École Centrale of Paris, an education to engineers which is altogether admirable, so far as that education can be given in colleges. They are all protected by an entrance examination, only a few degrees less severe than that required to win an appointment to the French polytechnic school; they have no posts or appointments to offer as prizes, and yet crowds of students annually strive hard to gain the mere privilege of admission.

How are we to explain this fact? The education at Zürich no doubt is cheap, but the fees for the École Centrale, which is a day-school, amount to £32 per annum. The subjects for the entrance examination, intended for young men of seventeen or eighteen, comprise a complete theoretical as well as a practical knowledge of arithmetic, algebra including quadratic equations, the binomial theorem, and the properties of logarithms and series, with the theory and use of the slide-rule, geometry plane and solid, descriptive geometry, involving the determination by geometrical methods of the exact forms of the intersection of various surfaces of revolution, as well as the ordinary conic sections, the elements of

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trigonometry, analytical geometry of three dimensions, the elements of physics, chemistry, and natural history, with drawing, described as geometrical, architectural, mechanical, and free-hand. Yet last year 500 pupils competed for admission, and only 220 were accepted, having absolutely no privilege whatever, except that of working very hard for three years, and paying £32 per annum in school-fees. An equivalent examination guards the German colleges, and yet Carlsruhe counts 451 students, of whom 148 will become engineers, and Zürich 681 technical students, of whom 206 are educated as civil and mechanical engineers. Some will tell you that this rush of young men to the large technical schools abroad is due to the appreciation by their parents of the great advantage of scientific training. In truth I believe this has very little to do with it. Parents, abroad as in England, are anxious that their sons should readily make a living, and therefore desire that their sons should follow the well-known and beaten paths which lead to recognised professions.

Now, abroad, this path to the work of an engineer lies through these great colleges. The English system of apprenticeship does not exist, consequently the one letter of recommendation which proves that a young man is worth a salary in an engineer's office, or in a mechanical workshop, is a diploma from a polytechnic school. Therefore the schools are full. In England, the path to employment as an engineer lies through the office or workshop of a civil or mechanical engineer, and therefore we find that young Englishmen and their parents crowd the doors of the offices and workshops, offering premiums of £300 or £500 for the mere permission to pass three years unheeded inside the magic gates, which must be passed to gain an entrance into the profession. True, abroad there is no law which requires a diploma from a man before he can practise. True, in

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Great Britain men may and do rise from the ranks, and become the most eminent of all our engineers, but it is not the less true that a young foreigner of education finds the only recognised entrance to his profession through the colleges, and that a young man here must look to pupilage or apprenticeship as the only recognised beginning to his career as an engineer.

The two systems cannot well be combined. The foreign plan requires a young man to study in a college till the age of about twenty-three, when it is too late for him to think of entering an office or workshop for three more years, paying a heavy premium and receiving no salary.

Before considering which is the best system, it will be well to give you a somewhat fuller account of what is done in these great technical schools. At Zürich and at Carlsruhe a staff of from forty to fifty competent professors gives a technical education to the students. Not only do they teach mathematics, mechanics, physics, geology, chemistry, but they teach how the knowledge of all these elements is to be applied to practical problems in every department of engineering. The pupil begins by designing screws, bolts, rivets, or walls, and culverts, and ends by designing, under the master's eye, the most complex machines and the most elaborate bridges and harbours; he is shown the practice of all nations; he is forced to calculate his work so as to meet the requirements of real problems, and so thoroughly is this done, that students do leave these colleges well able to earn a good salary in the drawing-office of the civil and mechanical engineer. I could not have believed this to have been possible had I not seen it; and my personal inspection of the colleges taught me to marvel at the combination of theoretical with practical knowledge evinced by the German Professors. At the École Centrale I found that the system was similar; in addition to the usual courses of lectures, projects were each month sub-

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mitted to each class; that is to say, they received a short specification of a certain work to be designed. The designs, specifications, and estimates were to be ready in one month's time. Meanwhile each pupil was free to consult books, friends, even the Professor himself, but he was bound to produce an original design, making the drawings in the class-room. When each design had been sent in, the Professor cross-examined every pupil as to his motives for choosing the dimensions, materials, and forms adopted, and finally, he corrected and criticised the design. Couple with this, admirable lessons in the higher mathematics, pure and applied, and you will not wonder that the École Centrale turns out men who are thorough masters of the theory and practice of design applied to engineering works.

This is the foreign system. What is ours?

Young men, at the age of about eighteen, enter the office of a civil engineer. Usually few questions are asked as to previous training. Etiquette requires the engineer to show a certain reluctance to receive the pupil, and, in fact, the ordinary pupil is a sort of nuisance in an office, only tolerated in consideration of the fee which accompanies him. From personal experience I can declare, that most pupils are so ignorant of algebra, that they are not only incapable of working out a result for themselves, but actually cannot apply the simple formulæ which are given in engineers' pocket-books. The calculation of the solid contents of a wall is often beyond their powers. Their arithmetic is very shaky, and a knowledge of physics, chemistry, geology, or the higher mathematics is wonderfully rare. The men have too often chosen the profession from an idea that it is pleasant, and because, forsooth, it is guarded by no preliminary examination. Not even a pass-examination is required, and the ignorance of some pupils, especially in mechanical workshops, must be experienced before it can be believed. They really seem to think that a

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little turn for making toy-models shows a bent for mechanical engineering such as will justify them in expecting success.

These young men during three years have the run of the office or workshop, and if they are intelligent, towards the end of their pupilage often have opportunities of seeing actual work in the field, or of designing some parts of actual machinery, and of assisting in the erection of more or less important works. No one teaches them anything; but they have the opportunity of seeing how some actual work is done; they see just how much mathematics is absolutely required, and they pick it up. They see how workmen are managed, and learn their habits; they are brought into contact with the exact class of work which they will have to perform, and they know that unless soon they are competent to do this work, they will not have a chance of employment. The one point for them is, to convince their masters that they are useful, and hence, notwithstanding their ignorance at starting, the neglect in which they are left during their pupilage, the absence of opportunities for improving their theoretical acquirements, many of them do become useful men.

The contrast between the two systems is complete: abroad, men have almost perfect theoretical instruction, coupled with a wonderfully good imitation of the real work, so far as design is concerned; they are not brought into contact with the execution of those designs until they begin to gain their bread. In England, the theoretical instruction is wofully deficient, but the abler men are allowed to design real work, and they watch the execution of that work in many stages. Abroad, competitive examinations keep out incompetent men; in Britain they are weeded out by the result of the struggle for existence. Abroad, great numbers pass through the same school, making the same designs, in great variety, under the same Professors. Here, each man sees different work, but of a limited kind.

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Before deciding which system is the best, or what modification of the two is desirable, we ought to form some idea of what the work of an engineer is.

As a civil engineer, the young man is called upon to design small works, such as bridges or culverts, according to some well-established type—little originality is wanted, and just so much theory as will allow him to make safely the slight modifications required to meet each case; he superintends the execution of work by contractors, and must know good from bad work when he sees it; he must have such a knowledge of mensuration as will allow him to certify exactly the quantities of work done by the contractor. He must be able to survey on occasion, to level with great rapidity and accuracy, and to set out work in the field. He must have such a knowledge of the world as will enable him to deal pleasantly and firmly with workmen, contractors, and proprietors on whose land the works are being constructed. Above all, he must be a thoroughly honourable man, wholly above suspicion of taking bribes from contractors, of cooking his work, of concealing any blunders he may make, or of absenting himself from his duties.

Colleges cannot teach young men all these things, and my own experience has confirmed the conclusion, that a gentlemanly man of fair education and intelligence, after working as a pupil for three years in a civil engineer's office, is, for subordinate positions as a civil engineer, a more useful man than the pupil of a foreign school.

For a mechanical engineer the case is different. The younger men in factories have to design machinery frequently of one type, but nevertheless varying so much from year to year, that a sound knowledge of mathematics, mechanics, and physics, is of the greatest importance to them; consequently as draughtsmen or designers we find foreigners employed all over the country. And *à priori* I would rather

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engage a foreigner to carry out my ideas in designing a new machine than a young Englishman of equal standing, especially as most of the foreigners complete their education by working in a shop for a short period.

As they rise in their professions, engineers are called upon to display higher and somewhat different qualities. The civil engineer may be called upon really to design great works and novel works; and here Englishmen feel sadly the want of a sound theoretical training. But even in the higher walks of the profession, design and invention are required much less than is usually supposed. The leading engineer must be a man of good business habits, able to advise the directors of great companies prudently as to the probable cost and revenue of proposed works. He must have the head of a lawyer in drawing up specifications and revising contracts. He must get into no scrapes by trying new-fangled schemes. He had better have no patents, which are generally supposed to be simply plans for getting money without giving any material equivalent. He must be able to choose his subordinates wisely, and keep them in good discipline. In a word, he must be a man of great *Common Sense.*

As a mechanical engineer, or as a contracting engineer, a knowledge of trade, a keen eye for economy in details, and a thorough practical knowledge of the properties of the materials he employs, must be added to the above list of talents; and when we reflect how very few of the above qualities can be taught at colleges, we understand how it is possible that our engineers should justly take a high rank in the estimation of the world.

You will long since have anticipated my conclusion,—that *there is no reason for abandoning our system of apprenticeship or pupilage to substitute for it the foreign plan of large special colleges,* even if we could hope to create colleges of equal merit with those formed abroad.

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But this conclusion, instead of leading us to sit down wrapped comfortably in a veil of blinding self-conceit, ought rather to urge us to work with the greater vigour at removing the acknowledged defects of the British plan. We have not to construct the whole edifice anew, we have only to put on the cornice-stone.

Our defect is the want of a good knowledge of the theories affecting our practice.

It must be admitted that of this knowledge we possess far less than is necessary. By dint of sheer hard thinking and repeated trials we somehow do solve most problems; and the plan of Brindley, who used to go to bed when he was posed, and think steadily for a day or two, is by no means a bad one. But our success costs a vast expenditure of money and of brain which could be turned to better purpose if we knew how to calculate the results to be expected from a given combination with some certainty beforehand. And not only does our ignorance cause much wealth to be wasted by the community in useless trials, but it prevents the trial of many new schemes, because the engineers or managers to whom they are submitted feel that they have no means of judging beforehand of the probability of success, so they, wisely in their generation, think they had better stick to the old plans, and in nine cases out of ten they are right; but the rejection of the tenth case is a dead loss to themselves and to the country. I do not know which is the sadder sight,—the hard struggle which awaits the true inventor before he can introduce his invention, or the miserable efforts of the vast crowd of ignorant men whose foolish fancies load the shelves of our Patent-Office. Poor men! they devote their fortunes, their time, their very lives, to the nurture of some mocking shadow, born of conceit and ignorance,—that ignorance which it is our business to banish from the land.

How much theory, as it is called, does the engineer want

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to enable him to judge soundly and design correctly? Certainly much less than is given abroad. At each college I visited, I asked what application these higher branches of mathematics and mechanics had to the practical work of an engineer. The first answer I received was that they were useful as gymnastics to the mind. I answered that I thought the mind might be more usefully exercised, and again asked what application could be made of this knowledge. The second answer agreed in three cases. Turbines, it appeared, could not be correctly designed without a very high theoretical training indeed; and our British turbines came in for a sneer. I used the vortex-wheel of James Thomson of Belfast as an answer, but had to confess my answer was not much to the point, as he is a most distinguished theorist.

Well, to me it hardly seems worth while for an engineer to spend three years in studying the higher branches of mathematics if these only find their application in turbines. Unquestionably these studies are necessary for the original investigation of novel problems; but the engineer in large practice will never have the time or inclination for such work as this, which will invariably be better done by such men as Sir William Thomson, Clerk Maxwell, Professor Rankine, or my colleague Professor Tait.

Those engineers whose natural bent lies towards such studies, will find them doubtless of great advantage; but in the general scheme of education for the profession they need not be included. This being so, I have no doubt that the *engineering student of average ability might acquire a sufficient knowledge of theory before his apprenticeship begins, or during its course.* The very entrance-examinations required by the foreign colleges are a proof of this. These examinations are passed by young men of seventeen, eighteen, nineteen, and if our pupils could enter on their apprenticeship as well educated as the foreigners when they

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enter their special schools, I am convinced that the British would in every respect be far superior to the foreign system. Our engineers would then start in life with a good knowledge of algebra, trigonometry, mensuration, drawing, the elements of physics and chemistry. The few who had the turn for higher mathematics could pursue their studies in after life, but all would be saved the weary time now lost in offices by zealous men trying vainly to understand the simplest formulæ, and gradually picking up through practice the power of mensuration, and of representing ordinary geometrical forms by mechanical drawing. In addition, it would clearly be of great advantage that they should, before being brought in contact with practical work, have had their attention drawn to the manner in which all these branches of knowledge are applied to the solution of practical problems, and this is the view I take of the duty which I have personally to perform. It is impossible in a single course of lectures to touch even cursorily on all parts of the vast field now claimed by the engineer as his domain. If it were possible, the mere cursory mention of the innumerable problems would be useless to the student; but it is quite possible to show the application of the theory of mechanics to the calculation of the strength of materials, and to the dimensions of the elements of machinery; it is quite possible to point out how in practice the stress to be borne by the various parts of structures comes to be determined. The practical application of the theory of energy and of work can be shown by a few examples chosen among the many engines from which man derives motive power. The manner in which estimates are made, specifications drawn, and contracts framed, can be indicated by special examples. Above all, it is possible to inculcate the true principles of economy upon the mind of the student, who should never forget that the object of the engineer is not to display his ingenuity by the production of ingenious devices, but to use his

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judgment and invention so as continually to endeavour to increase production at a diminished cost.

Thus, by first explaining the nature of the elementary materials and forms with which the engineer has to deal, and by then analysing the construction of known practical examples, I hope to send my students to the offices and workshops of my fellow-engineers really well prepared to make a good use of their opportunities, and able to apply to the endless variety of problems which they will encounter, those principles, the application of which they have learned in a few cases here. If, moreover, the students will attend the classes of natural philosophy, mechanics, mathematics, and chemistry, if they will take advantage of the facilities given for acquiring a knowledge of drawing, of surveying, and levelling, and of inspecting, under my guidance, practical examples of works, machinery, and processes of manufacture, we shall, I think, do much to solve the problem of how to improve the education of our young engineers in matters of theory without sacrificing the valuable element of practice obtained by the system of pupilage; *and this work can, I believe, be far better done at a university than in any new special schools.* You observe that I count upon having the work done even more by my colleagues than by my own exertions,—I wish my engineering pupils to owe quite as much to Professors Kelland, Playfair, Tait, as to me. Does any one think that a new polytechnic school, started in rivalry with the university, could count on such Professors as these? I do not; and if the new school did attract such men, it would weaken our ancient universities, in which we all feel so legitimate a pride. Abroad, I saw this in action. At Zürich, the polytechnic school dwarfs the university; and in French universities, the scientific teaching has fairly been extinguished by the polytechnic school. Hardly a student of science attends a class in the universities. The

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reason given me for the separation was the want of elasticity in the foreign institutions, which, owing to their charters or their prejudices, could not so change their practice as to meet new requirements. We in Scotland are wiser. The domain of exact science grows day by day, and instead of jealously denying honour to new branches of learning, instead of shutting their gates to the students of new professions, the Scottish universities aspire to lead the way, and to guide the student on every path that leads to knowledge.

Surely this is preferable to the extinction of ancient institutions, with their grand traditions. Moreover, though I am one of those who believe that science will more and more become the instrument of culture for a large class of minds, I am far from insensible to the great value of that form of culture which hitherto has been given almost exclusively by classics and metaphysics. I have said enough to show that the leading engineer must be no mere calculating-machine, but that he requires a breadth of knowledge and openness of mind which can seldom be acquired by those who are ignorant of literature, and who have not obtained at least a distant view of the great sea of metaphysical speculation. For this reason, if for no other, I would fain see young engineers pass through such a university as this, famed above all for its influence on the studies of ethics and mental science.

If universities are to supply methodical instruction for new professions, so as to render unnecessary the erection of special schools of narrower scope, they must not only found certain Chairs, but must group into well-considered courses of study the subjects required by the students of these new professions. Consider how unsatisfactory the education of medical men, for instance, would be, if each student were simply free to follow what courses he pleased, in any order he pleased,—if there were no curriculum to guide him, no methodical examination testing his acquirement, no degree

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certifying the measure of his attainments. Engineering is a younger profession, but one no less well defined or less recognised by the world than that of medicine, and a curriculum or methodical course of study, examinations, and *degrees or diplomas of some kind are really as necessary to insure methodical study by the engineers as by the doctors of medicine or the doctors of law.* A natural, and indeed a healthy, aversion exists to the creation of new degrees, or even new examinations, diplomas, and certificates; but unless some distinct aim less vague than future and far-distant professional success be held out to the student, I fear it will be hopeless to expect him to follow that methodical course of study which I regard as essential. Diplomas of engineering are no novelties abroad; they are granted by all the large and successful colleges; they are the object of a most legitimate ambition, and testify to facts which can be ascertained with certainty. No diploma could be granted by this University certifying that a man who had only studied here was fit to practise the profession of an engineer; a diploma following on college studies ought only to declare that the student is fit to enter the office or the workshop with advantage to himself and his employer; but there is no reason why, after some years of practical work, the engineer should not return to the university, and by passing a voluntary examination, both in matters of theory and of practice—such an examination as is actually conducted in Germany,—obtain a degree or diploma which should really be a guarantee that in certain branches he was a competent engineer. The arguments in favour of an Engineering degree may be thus shortly stated:—the profession is well defined; the studies required by its followers are of a scientific kind, well suited for collegiate examination; a motive for systematic study is urgently required; and, lastly, a means of distinguishing themselves is earnestly desired by young

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engineers on the termination of their pupilage. Now, personal distinction is wholly denied to the young engineer; he works for others, and the merit of his work falls to the credit of his employer, who is responsible for it to the outer world; some means of distinction, such as is afforded by a degree, would greatly tend to induce men, after leaving the university, to continue their studies. I really know of no objection to the creation of a degree or the granting of a diploma, except that it is a novelty in Great Britain, and might be misused by inferior institutions.

When all this has been done, as I hope it will be done, our difficulties are far from being at an end. We must not only provide a methodical education, but we must induce students to avail themselves of it. As I said before, foreign colleges are full of students, because the only paths leading to practice lie through these colleges, and if the engineering students at our universities are to be numerous, the universities must become the recognised portals of the profession. We can do something by giving sound instruction, but the effect of this on the public mind must necessarily be slow, for the fruits of good teaching, given to a small number, can only be slowly felt. We may therefore call upon those outside our walls, who have faith in scientific teaching, for assistance. I cannot show better how this might be done than by referring to some of the resolutions arrived at by the committee of the London Society of Arts on technical education. This committee, composed of men of great weight, recommend that the Government and the leading civil or mechanical engineers should co-operate with the universities in examinations for diplomas or degrees. Such a co-operation would guard us against a species of Dutch auction, in which inferior colleges might possibly engage, giving the new degrees with more and more facility, for continually smaller acquirements, in the hope of attracting

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pupils. The committee further recommend that the engineers and the Government should give a practical value to the diplomas or degrees granted with their co-operation, by the following steps:—1. Reducing premiums to intending pupils holding diplomas; 2. By giving weight to the possession of diplomas by candidates for employment; 3. By granting distinct privileges in connexion with the great professional institutions; 4. Government might give official value to the diplomas, by allowing these to represent a given number of marks in competitive examinations; 5. By putting at the disposal of universities which give diplomas of recognised value a limited number of nominations annually; 6*th*, and lastly, By acting with the same liberality which Government has shown in endowing this chair; by assisting old and new endowments, where private subscriptions or donations prove the value set on the instruction proposed or given.

When we find a committee composed of such members of Parliament as Mr. Samuelson and Mr. Acland, such men of business as Sir Daniel Cooper and Mr. Hawes, such professors as Williamson, Huxley, and Hirst, and Miller, such engineers as Hemans and Pole, all concurring in their readiness to establish and recognise diplomas of Engineering, we may surely admit that the time is ripe for the creation of such diplomas, and the recommendations made in their report may safely be acted upon by the leading professional men, by Government, and by this University. If Engineering departments in universities come to be supported in the manner proposed, the great bulk of our young engineers will soon pass through our Science classes, and the profession be relieved from the degrading charge of ignorance of first principles, and of the theory of their application. I am sanguine enough to believe that these things will come to pass, and bold enough to hope that this University will lead the way.

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Some difficulty may be found in leading a few of the older members of our profession to recognise the value of scientific study. It will be our business to convince them of their error, and, when convinced, no body of men will evince greater liberality or zeal in furthering the interests of the profession, as has been recently proved in Manchester by the endowment of the Chair in Owens College, and by the splendid munificence of Mr. Whitworth.

In conclusion, let us consider the path over which you have followed me. We found in the polytechnic school of France and the English system of pupilage two wholly different plans, aiming at one end, each with grave faults. Intermediate between the two, I described the action of the École Centrale of Paris and the polytechnic schools of Germany, admitting their success. Nevertheless, after reviewing the work required from the engineer during his professional career, I argued that in Great Britain we should not tamely copy institutions which do not fit with the established custom of this country, but should rather endeavour to develop our own method, successful in the main, by adding to the practical teaching given by pupilage that theoretical preparation now wanting. I endeavoured to show that this preparation could be given before the age at which men enter works or offices, and showed in illustration that foreigners, at that age, did pass examinations of far greater difficulty than those which are now held by Government to determine the selection of engineers for civil posts in India. Next came the question whether special schools or ancient universities are best fitted to give this preparation, and I can hardly doubt that your hearts will re-echo, with just pleasure, the arguments, which reason alone dictated, in favour of our ancient College. Lastly, I indicated the nature of the support which would most effectually insure that the opportunities now granted shall be effectually used. But I have not yet named

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the main source of support on which I count, the main grounds of my confidence in success,—the zeal and energy of the Scottish student.

I have spoken tamely and coolly of the life and duties of an engineer; for it was necessary to reason calmly in weighing the merits of rival systems. I spoke of common sense as the cardinal virtue of an engineer, and we in Scotland fairly claim, I believe, more than the average share of that commodity. But more than this is required. No one who, as a mere business speculation, coldly chooses a profession, will ever rise to great eminence. Zeal and devotion to the work are wanted. The profession of an engineer offers ample scope for the exercise of such feelings. We see him taming Nature's forces till they become his servants, creating wealth for nations by the exercise of invention, commanding armies of men, who, labouring to their own benefit, yet shape their work till it embodies the idea of one mind, for whom Science herself toils as a handmaid,—who then shall say that the work of an engineer, which can be thus described, is not a fit subject for *enthusiasm?*

EDINBURGH: T. CONSTABLE,
PRINTER TO THE QUEEN, AND TO THE UNIVERSITY.

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